CHAPTER FOUR
RESULTS

4.0 Introduction

The vowels of a total of 30 speakers (15 males and 15 females) were measured and values obtained in hertz (Hz) for the ten short vowels [i, ɪ, ə, e, ɛ, a, ɔ, o, ɷ, u] and their longer counterparts [i:, e:, a:, o:, u:] for the various dialects of Dagbani (Nayahili, Nanuni, and Tomosili). Formant frequency values for the lowest two formants, F1and F2, were measured, out of which the F2' (F2-F1) values for each token of three repetitions per vowel for individual speakers were calculated. The resultant formant frequency values for F1 and F2' were used to plot the vowels of the dialects on the formant charts in this study. For the measurement of duration speakers' vowel formants were measured in seconds and later converted into milliseconds for the analysis. The duration analysis involved comparison of vowel length between dialects and gender.

4.1 Frequency Data Analyses

Tables 2 and 3 contain the means and standard deviations of the first two formants (F1 and F2) and F1 and F2 difference (F2') of each vowel at the target position for the Tomosili, Nayahili and Nanuni dialects of Dagbani. Each formant value in tables 2 and 3 is a mean of 30 tokens of a vowel for three repetitions across ten speakers. Tables 4 and 5 show the overall mean formant values across the thirty speakers under study. Every formant value in tables 4 and 5 is a representative of 90 tokens of a vowel across 30 speakers. The target F1, F2, and F2' values are discussed in detail here.

4.2 Results of the Various Dialects

Analysis of variance (ANOVA) were carried out in SPSS with a level of significance of $p<.05$ and with post hoc t-test having a p value of .005.

Table 2: The means and standard deviations in hertz for F1, F2 and F2' for each monophthong at the target for Tomosili, Nayahili and Nanuni

vowel	Mean & std.	Tomosili			Nayahili			Nanuni		
		F1	F2	F2'	F1	F2	F2'	F1	F2	F2'
i	Mean	345	2212	1867	348	2267	1919	338	2155	1817
	Std.	50	313		31	270		41	275	
□	Mean	357	2160	1803	332	2239	1907	332	21.96	1864
	Std.	41	341		60	198		59	250	

ə	Mean	479	1543	1064	455	1709	1254	499	1809	1310
	Std.	85	396		31	262		39	362	
e	Mean	455	1995	1540	433	2082	1649	459	2027	1568
	Std.	86	150		54	361		54	212	
ɛ	Mean	455	2058	1603	447	2057	1610	509	2061	1552
	Std.	64	264		53	217		55	275	
a	Mean	733	1505	772	743	1480	737	771	1486	715
	Std.	39	119		61	166		59	143	
ɔ	Mean	572	1130	558	563	1133	570	642	1009	367
	Std.	72	101		86	126		74	323	
o	Mean	467	916	449	459	881	422	564	976	412
	Std.	82	118		61	78		47	96	
ɷ	Mean	413	903	490	397	861	464	447	808	361
	Std.	33	119		52	84		63	69	
u	Mean	379	1062	683	346	906	560	408	1007	599
	Std.	45	87		39	165		68	109	

Table 3: The overall means and standard deviations in hertz for F1, F2 and F2' of each long vowel at the target across 30 speakers of the Tomosili, Nayahili and Nanuni dialects of Dagbani

vowel	Mean & std.	Tomosili			Nayahili			Nanuni		
		F1	F2	F2'	F1	F2	F2'	F1	F2	F2'
i:	Mean	361	2452	2091	308	2312	2004	336	2274	1938
	Std.	28	422		42	191		66	270	
E:	Mean	408	2213	1805	431	2148	1717	512	2085	1573
	Std.	42	277		69	189		54	232	
A:	Mean	804	1552	748	796	1514	718	832	1537	705
	Std.	34	149		69	177		67	167	
O:	Mean	413	1036	623	445	1051	606	518	1104	586
	Std.	49	91		61	86		53	86	
U:	Mean	409	914	5505	390	797	407	414	816	402
	Std.	32	351		43	82		66	121	

Table 4: The overall means and standard deviations in hertz for F1, F2 and F2' of each short vowel at target for the 30 speakers of the Tomosili, Nayahili and Nanuni dialects

		i	□	ə	E	ɛ	a	ɔ	o	ɷ	u
F1	Mean	344	340	478	457	470	749	592	497	419	375
	Std.	40	53	58	68	62	55	83	79	53	55
F2	Mean	2211	2198	1687	2035	2059	1490	1091	924	857	987
	Std	280	262	351	252	244	139	209	103	98	140

F2’	Mean	1867	1858	1209	1578	1589	741	499	427	438	612

Table 5: The overall means and standard deviations in hertz for F1, F2 and F2’ of each long vowel at target across 30 speakers of the Dagbani

		i:	e:	a:	o:	u:
F1	Mean	335	451	811	459	405
	Std.	51	71	59	69	48
F2	Mean	2346	2149	1534	1064	842
	Std.	309	233	160	89	218
F2’	Mean	2011	1698	723	605	437

The Oneway ANOVA was used to examine separately F1 and F2 for speakers of the various dialects comparing the significant differences that exist between the formants of speakers of each dialect. A similar examination was carried out on the mean formant values for the various dialects to examine the level of interaction between the dialects. These results are presented by dialects; and finally a combination of the three dialects to sum up for the language.

4.2.1 Results for the Nayahili Speakers

Ten speakers made up of five men and five women were recorded and data analyzed for the Nayahili dialect. Table 6 is a one-way ANOVA test results for the comparison of the significance of vowel production between Nayahili speakers.

Table 6: Oneway ANOVA comparing the level of significance for vowel production between the speakers of Nayahili

Vowel	*Df*	*F*	*p*
i	9	.091	1.000
	9	.050	1.000
ə	9	.219	.988
e	9	.227	.986
ɛ	9	.089	1.000
a	9	.197	.992
ɔ	9	.183	.994
o	9	.120	.999
ʊ	9	.109	.999
u	9	.403	.919

The *p* values in Table 6 show no significant differences between the Nayahili speakers for the production of their vowels. This means that the Nayahili speakers under study produce the vowels of Dagbani in nearly the same way. Results for the test for significance for their F1 and F2 did not show any significant difference either. The Tukey estimation formula was used for the post hoc analysis with a harmonic mean sample size of 10.00. Means for groups (F1 and F2) in homogeneous subsets provided the level of significance without any significant difference between speakers' formant measurements for all ten short vowels.

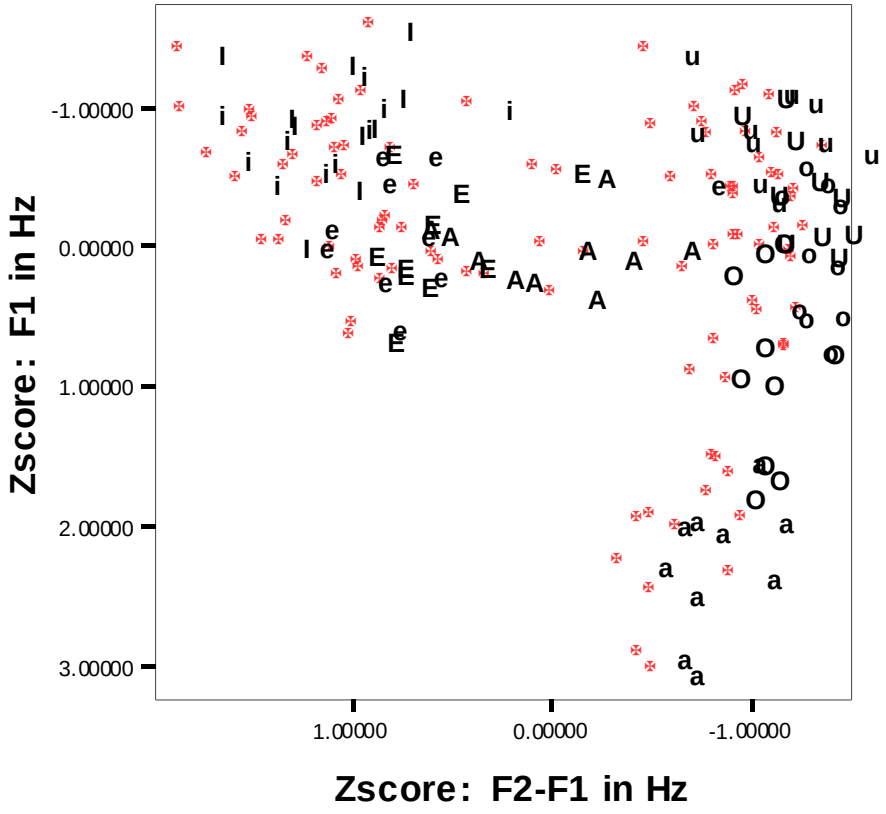

Figure 4: F1/F2-F1 scatter plot of the vowels of the Nayahili speakers. I=□; E=ɛ; A=ə; O=ɔ; U=ɷ

Figure 4 displays a scatter plot of the resultant formant values of the vowels of the Nayahili speakers. The scatter of the vowels shows the differences that exist between the formant values of the various speakers. The spread of [i] from the

high central position of the vowel space to a fronted position on figure 4 shows speakers' F2 variance. Figure 4 also shows overlapping of some vowels. [i] and [□] cluster together in the front high area of the vowel space while [e] and [ɛ] cluster together in the mid front position of the vowel space; however, some speakers' [e], [ɛ] and [□] overlap in the front mid high area of the vowel space. A majority of tokens of the vowels [ɷ] and [u] are located in between F2 values of 300 and 400Hz. The scatter displays some distinction between [ɔ] and [o] with a few tokens of [ɔ] overlapping with the tokens of [o]. These vowels occupy the mid back area of the vowel space. The distribution of [a] shows slight variation in both F1 and F2 differences among speakers. The position of the tokens for [u] shows low F1 for a good number of the Nayahili speakers as compared their high front vowels. Many of the [u] tokens are also much fronted. The tokens for [ə] (A) occupy the central part of the vowel space. The positions of these tokens indicate lower F1 values since they appear above 500Hz. The overall mean vowel plot for Nayahili in figure 5 confirms these characteristic features.

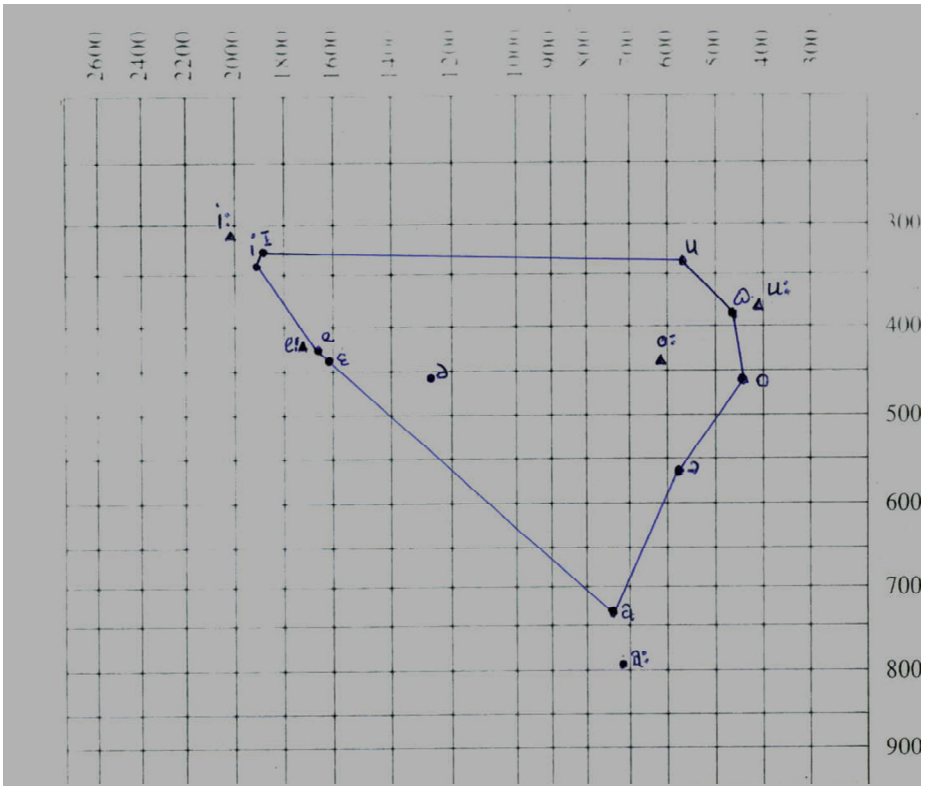

Figure 5: F1/F2-F1 mean plots at target position of the long and short vowels of the Nayahili speakers.

Figure 5 is the acoustic vowel map illustrating both long and short vowels as produced by the Nayahili speakers. The figure shows that no significant differences exist between the vowels [i] and [□] and also [e] and [ɛ] for the Nayahili speakers. This feature is also proved by the paired vowel test for the dialect in table 10. However, [i:], the long counterpart of [i] is realized in a most higher and fronted position. There are no significant F1 and F2 differences for [e] and [ɛ]. The figure also shows that [e:] is more front than both [e] and [ɛ]. Much clearer distinctions are noticeable for the back vowels [o], [ɷ] and [u]. The figure shows that [o:] is slightly higher and more front as compared to its shorter counterpart [o]. [u:] appears significantly lower (as low as /ɷ/) and back as compared to [u]. The position of [ɔ] is distinctive in the back low mid position of the vowel space. Both [a:] and [a] have the feature of much openness with significant location difference in the Nayahili dialect. Thus, as can be seen in Figure 5, the Nayahili speakers have their vowels as [i, □], [e, ɛ, e:], [ə], [a], [ɔ], [o], [ɷ, u:], [u], [i:], [a:] and [o:], that is eight short vowels and five long vowels.

4.2.2 Results for the Nanuni Dialect

Table 7 shows the analysis of variance test results for the significant differences for vowel production between speakers of the Nanuni dialect. The values of *p* in Table 6 show that there are no significant differences between speakers in their production of the ten short vowels of Dagbani. In a post hoc analysis with a harmonic mean sample size of 10.000 for the first two formants of their vowels, the Nanuni speakers displayed no significant differences in their measurement.

The results of the Oneway ANOVA tests are reflected in figure 6 as the distribution of the vowels can be seen in their respective areas of the vowel space. The cluster of each vowel is indicative of variation for both F1 and F2 for the vowels of speakers. F2 values for the high front vowels [i] and [□] spread from the centre of the vowel space to a more fronted position. F1 variations of these two sounds are realized as they spread from the front high position to the mid front area of the vowel space. The cluster of [e] and [□] in the front mid area of the vowel space indicate the interrelated nature of their formant frequencies. The majority of [ə] tokens fall within the mid central area of the vowel space with little variation of F1 values between speakers

Table 7: Oneway ANOVA comparing the level of significance for vowel production between the speakers of Nanuni

Vowel	*Df*	*F*	*p*
i	9	.105	.999
□	9	.083	1.000

ə	9	.373	.935
e	9	.080	1.000
ɛ	9	.139	.998
a	9	.144	.997
ɔ	9	.286	.971
o	9	.139	.998
ɷ	9	.105	.999
u	9	.083	1.000

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The spread of [a] in the low back area of the vowel space indicates no significant difference in F1 for a majority of the Nanuni speakers; however, a few outliers are realized in the area of [ɔ] in the vowel space. The tokens of [ɔ] occupy the mid low area of the vowel space with slight differences on F1 and F2. [o] is scatted in the mid back region of the vowel space with a few tokens falling in the area of [ɔ] described above; an indication of high F1 values for [o].

The vowels [ɷ] and [u] cluster together, spreading from the back high to the back mid high areas of the vowel space. The scatter plot in figure 6 shows overlaps in the speakers' production of [ɷ] and [u].

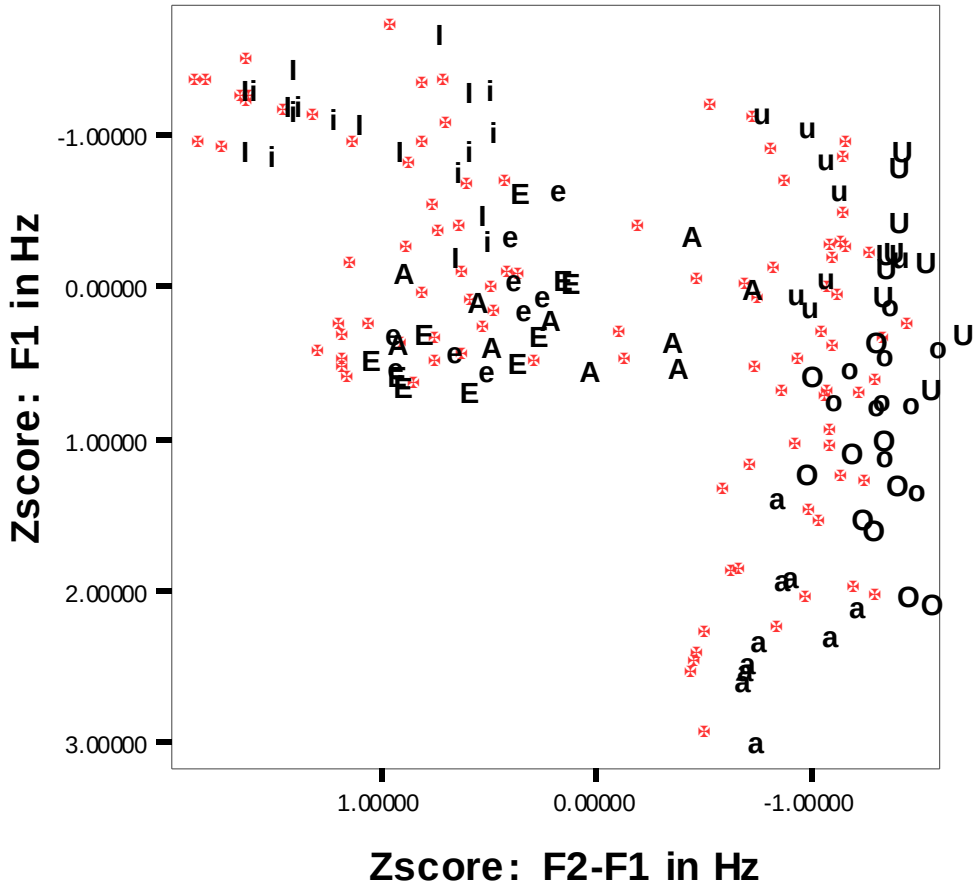


Figure 6: F1/F2-F1scatterplot of the vowels of the Nanuni speakers. I=□; E=ɛ; A=ə; O=ɔ; U=ɷ

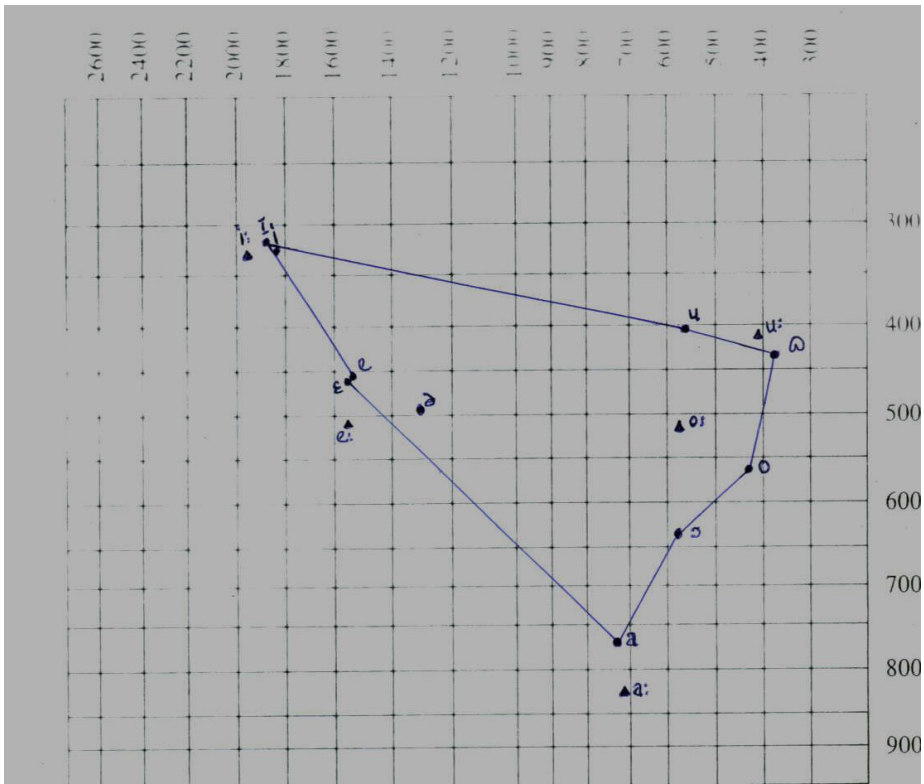


Figure 7: F1/F2-F1 mean plots at target position of the long and short vowels of the Nanuni speakers.

The mean plots in Figure 7 shows a clear distinction between the back vowels [u, ɷ, o, ɔ]. There is however a centering of [u] as compared with its longer counterpart [u:] in the high back area of the vowel space. [a] and its longer counterpart ([a:]) are located in the back low area with [a:] significantly lower F1 than [a]. [ə] is more fronted in the mid central area as it appears very close to [e] and [ɛ] which are in the mid front area of the vowel space. The Nanuni [e] and [ɛ] do not differ significantly in both F1 andF2. Figure 7 shows that [e:] is significantly different from both [□] and [e] for the Nanuni speakers. [i] and [□] appear not to have any significant differences as they are located in the high front position of the vowel space. [i:] is also located in the area of [i] and [□] with slight F2 difference indicating fronting of [i:] for Nanuni speakers. The vowels for the Nanuni speakers can be summarized as [i, □], [e, ɛ], [e:], [ə], [a], [ɔ], [o], [ɷ], [u], [a:], [o:] and [u:], that is eight short vowels and five long vowels.

4.2.3 Results for the Tomosili Dialect

The Oneway ANOVA results in Table 8 tests for the significant differences that exist between speakers in their production of the ten short vowels of Dagbani. No significant differences are noted between speakers for their production of the vowels. The ten speakers of Tomosili in a post hoc analysis displayed no significant difference for the first two formants frequencies of their vowels.

Table 8: Oneway ANOVA testing the level of significance for vowel production between the speakers of Tomosili

vowel	*Df*	*F*	*p*
i	9	.130	.998

□	9	.164	.996
ə	9	.604	.779
e	9	.046	1.000
ɛ	9	.133	.998
a	9	.096	.999
ɔ	9	.119	.999
o	9	.250	.981
ɷ	9	.261	.978
u	9	.071	1.000

This means that the Tomosili speakers have very common characteristics in the production of their vowels.

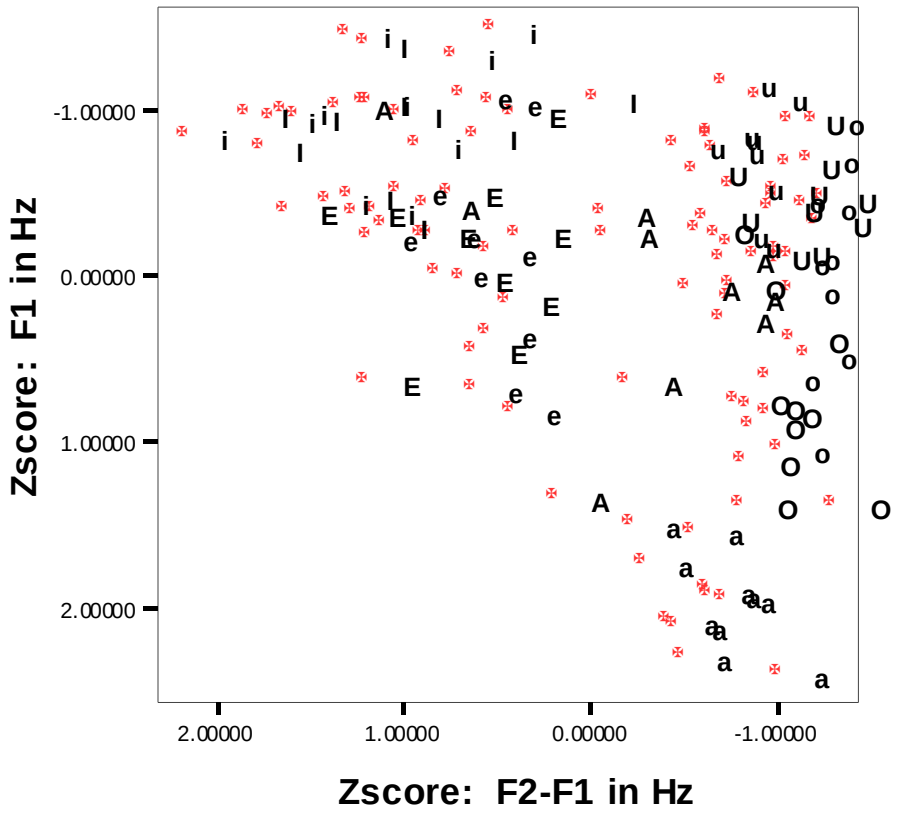


Figure 8: F1/F2-F1 scatter plot of the short vowels of the Tomosili speakers. I=□; E=ɛ; A=ə; O=ɔ; U=ɷ

Figure 8 shows the scatter plots of mean values for the short vowels at target positions in hertz (Hz) for the Tomosili dialect. The figure shows the spread of [i] and [□] from the high front area of the vowel space. In this high front area of the vowel space, the outliers of [e], [ɛ] and [ə] are found clustering with [i] and [□]. The tokens of [e] and [□] spread from the high front mid area down into the low mid front area of the vowel space; indicating some degrees of F1 significant differences between speakers' production. [ə] occupies the centre of the vowel space with some tokens realized in the back mid low and low central areas of the vowel space. The tokens of [a] cluster in the lower back area of the vowel space. The cluster of [ɔ] indicates no significant F1 and F2 differences between speakers in the back mid lower area. Tokens of [o, ɷ, u] scatter with overlaps in the back mid area, back mid high and high back areas respectively in the vowel space.

Figure 9 is the summary of the Tomosili vowels shown in Figure 8. Figure 9 show that the Tomosili speakers have both [i] and [□] in the high front area of the vowel space with [i] slightly higher than [□]. [i:] is slightly lower and fronted as compared to [i] and [□]. The Tomosili vowel space shows that [e] and [ɛ] are not significantly different for both F1 and F2. However, [e:] appears quite distinct mid way between [i, □] and [e, ɛ]. The two tokens of [a] and [a:] are very low and towards the back with significant F1 difference placing [a:] lower than [a]. [ə] is at the mid central area of the vowel space. The back vowels are clearly separated out with [u] fronted in the high back. [u:] and [ɷ] appear almost as the same vowel for the Tomosili speakers. While [o] appears as a mid back vowel, [o:] appears as high as the Tomosili [ɷ], thus, placing it with only F2 difference with [u:]. [ɔ] lies in the mid low back area of the vowel space.

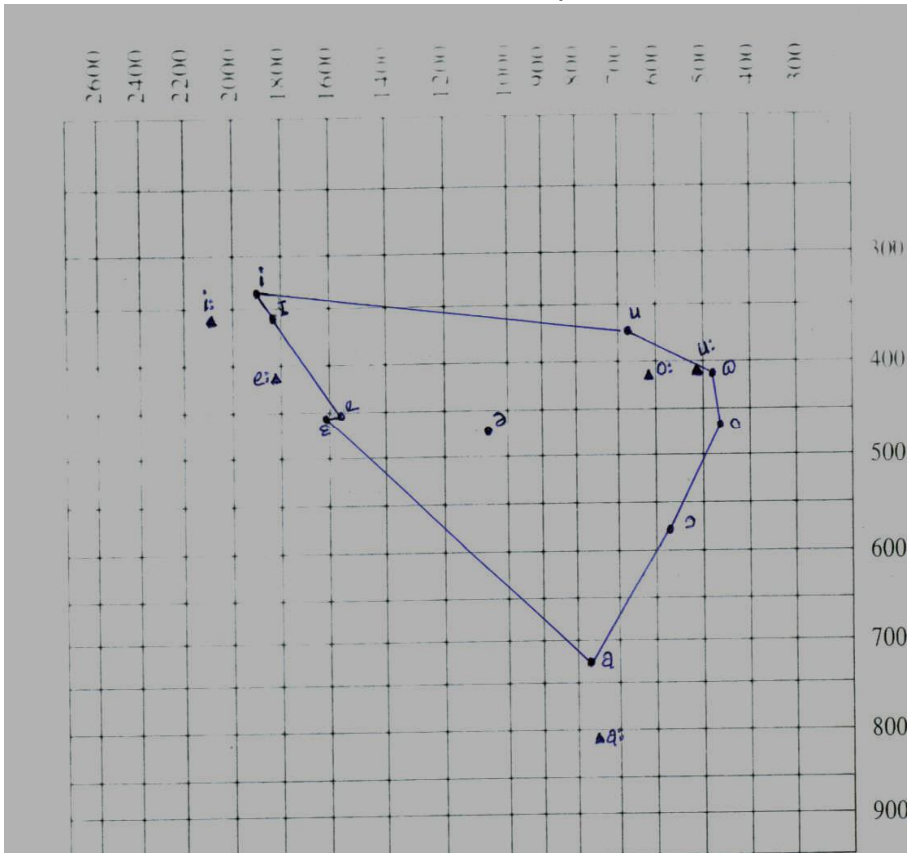


Figure 9: F1/F2-F1 mean plot of the long and short vowels of the Tomosili speakers.

The vowels of the Tomosili dialect can thus be summarized as [i, □], [e, ɛ], [ə], [a], [ɔ], [o], [ɷ, u:], [u], [i:], [a:], [e:] and [u:], that is eight short vowels and five long vowels.

4.2.4 Results for comparison between the dialects

Table 9 is the result of Oneway ANOVA testing the degree of significant differences between the formants for the thirty speakers of Nayahili, Nanuni and Tomosili dialects. The level of significance is $p<.05$ and a post hoc significance of .005. In separate tests for F1 and F2 the results displayed a higher degree of non-significant differences between speakers for F1 and F2 for speakers' vowels. However, the results display significant differences for F1 for [□] and [o] and F2 for [u].

Table 9: Results of Oneway ANOVA comparing F1 and F2 separately for the speakers Nanuni, Nayahili and Tomosili

Vowel	Parameter	*Df*	*F*	*p*
i	F1	2	.145	.866
	F2	2	.386	.684
□	F1	2	.704	.503
	F2	2	.217	.806
ɨ	F1	2	1.461	.250
	F2	2	1.529	.235
e	F1	2	1.481	.246
	F2	2	.291	.750
ɛ	F1	2	3.460	.046
	F2	2	.000	1.000
a	F1	2	1.358	.274
	F2	2	.087	.917

ɔ	F1	2	3.103	.061
	F2	2	1.169	.326
o	F1	2	7.986	.002
	F2	2	2.337	.116
ɷ	F1	2	2.470	.103
	F2	2	2.589	.094
u	F1	2	3.315	.054
	F2	2	3.657	.014

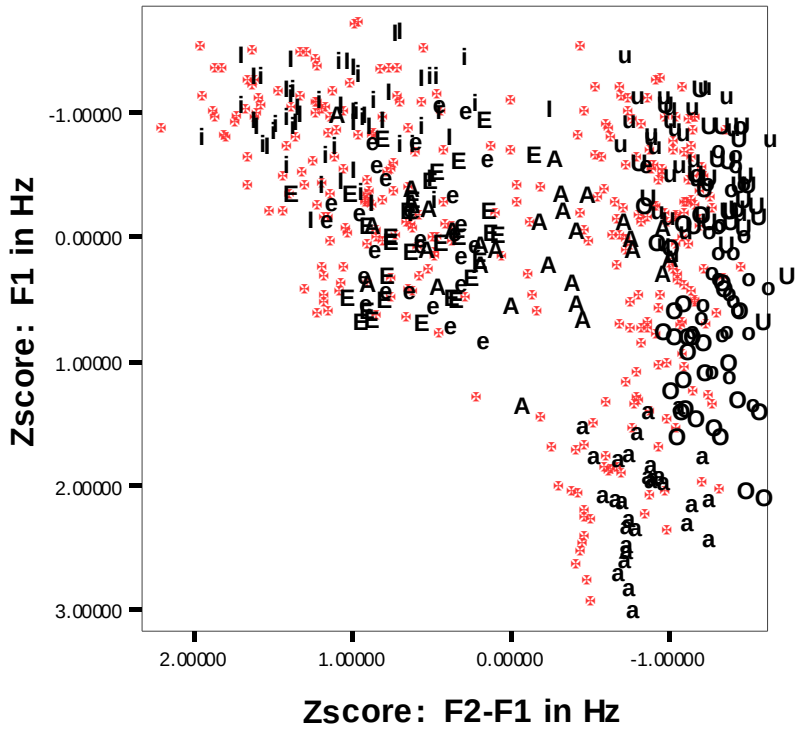


Figure 10: F1/F2-F1 speaker mean scatter plot of the short vowels of the three dialects (Nayahili, Nanuni and Tomosili). I=□; E=ɛ; A=ə; O=ɔ; U=ɷ

The scatter plot in Figure 10 indicates these relationships between the vowels of the various speakers. Some characteristics that are evident in the scatter plots are the clustering of the vowels at various areas of the vowel space. For instance the front vowels [i, □, e, ɛ] cluster in the mid front to the front high positions of the vowel space with [e] and [ɛ] in the former and [i] and [□] in the later positions. The scatter plot also indicates the lower and back nature of [a]. The tokens of [u] are low as compared the height of the front vowel [i]. The other back vowels spread over the vowel space from the back mid low area through the mid back to

the back mid high position. Figure 11 gives a summary of the characteristics exhibited by the vowels of the various dialects.

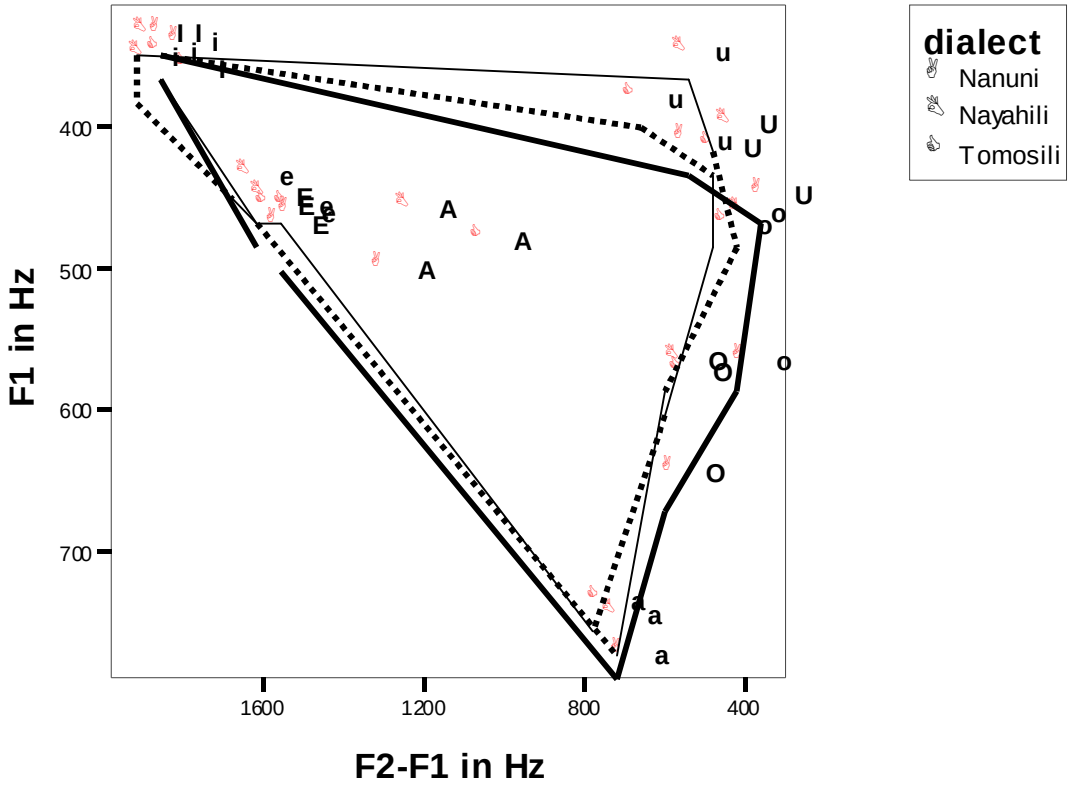


Figure 11: F1/F2-F1 plots of the mean values for the three dialects. I=ɪ; E=ɛ; A=ə; O=ɔ; U=ɷ

Figure 11 is a representation of the mean values of vowels in Hz for all the three dialects, a combination of figures 5, 7 and 9. All three dialects display no significant difference for the high front vowels [i] and [□] (cf. table 11). The three vowel spaces in figure 11 show that [i] and [□] have no difference in both F1 and F2 across all three dialects. All the dialects have [e] and [ɛ] located in the front mid position without significant difference. This means that speakers of the three dialects produce [e] and [ɛ] nearly the same way. [ə] is central for all dialects with Nanuni being the most fronted. Nayahili [ə] is most high while that of Tomosili is most back. Slight differences (not significant) exist for [a] between the three dialects with Nayahili [a] realized midway between those of Nanuni and Tomosili.

Nanuni [a] is the lowest towards the lower back of the vowel space. Nanuni [ɔ] is clearly located in the lower mid back area of the vowel space while those of Nayahili and Tomosili appear as almost the same and as high as Nanuni [o] in the mid back position of the vowel space. The differences here are as a result of higher F1 values for the back vowels of the Nanuni speakers. Nayahili and Tomosili [o] also occur together with Nanuni [ɷ] in the back mid high position of the vowel space. Nanuni [u] occurs with [ɷ] for Nayahili and Tomosili in the high back area. While Tomosili [u] is most fronted that of Nayahili is most high and with almost the same F2 value with that of Nanuni.

The vowel spaces for the three dialects in figure 11 are not significantly different, however, the few differences distinguishing them are found in the lower and back vowels. As a result of higher F1values for Nanuni vowels, its vowel space is lowest and most back. The difference between the vowel spaces of Tomosili and Nayahili is realized in the back vowel [u]. Nayahili [u] is higher, indicating a slightly larger vowel space than Tomosili. The uniform characteristics of the front vowels for the three dialects display no significant difference between the vowel spaces in the front area.

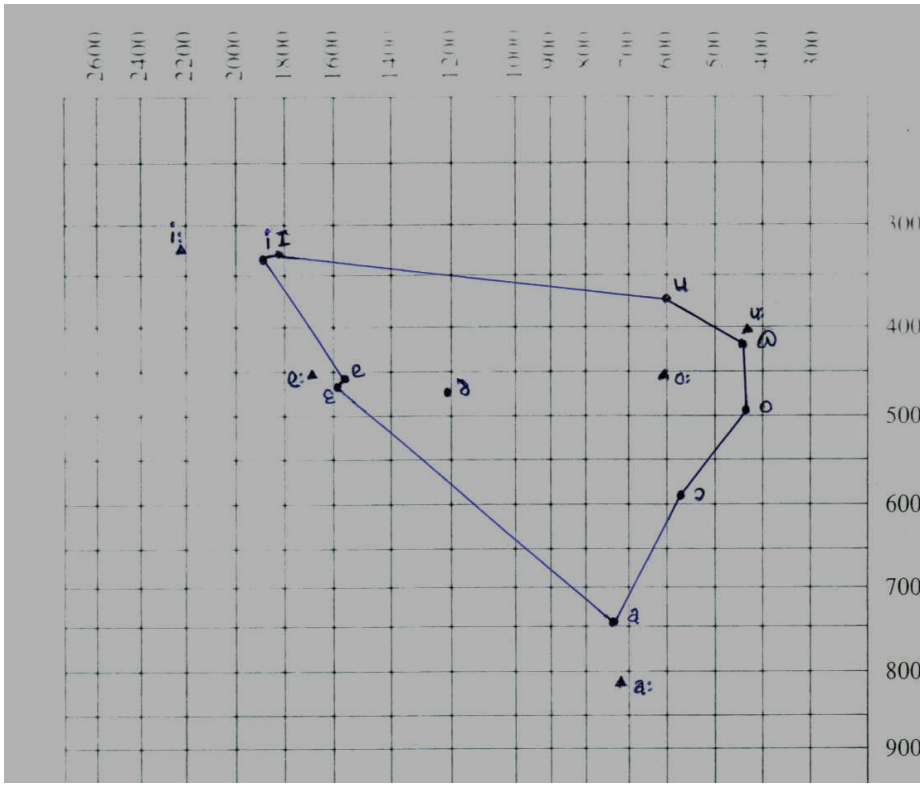


Figure 12: Overall mean representation of Dagbani vowels.

4.2.5 Representation of the Dagbani vowel space

Figure 12 is the representation of the vowel space of Dagbani as indicated by the current data. Each vowel here is an overall mean representation of approximately 90 tokens of a vowel pulled across 30 speakers; a single speaker having a maximum of 3 tokens per vowel.

The vowel space gives an indication of [i] and [□] appearing as one vowel in the high front region of the vowel space. [e] and [ɛ] appear with no significant difference in the mid font position. [a] appears as a lower vowel in the position towards the back than central. The back vowels [ɔ, o, ɷ, u] distribute themselves among the areas back mid low, mid, mid high, and high of the vowel space respectively. The front long vowels [i:] and [e:] appear slightly fronted than their short counterparts [i] and [e] respectively as a result of high F2 values. [a:] is significantly lower than its short counterpart [a] towards the low back area of the vowel space. [o:] is higher and fronted than [o] while [u:] is lower (as low as [ɷ]) and back than [u].

4.3 Paired Vowels Test

The paired vowel test is aimed at investigating the validity of the impressionistic claim that some pairs of vowels of Dagbani are allophones of various phonemes. The pairs of vowels that were tested are [i] – [□]; [i]-[ə], [e] – [ɛ]; [ɔ] – [o] and [ɷ] – [u]. The mean target values for the vowels were tested separately for the various dialects, and a final test combined the overall means of the dialects to test for the language. The statistical device that was used for the tests is the Paired-Samples Test. All test were performed at a 95% confidence interval level $p<.05$.

4.3.1 Paired Vowels Test for Nanuni

The table below presents the paired vowel test results for the Nanuni dialect.

Table 10: Paired Samples Test results showing the significant differences between vowels for Nanuni.

Paired Vowels	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
i - □	22.05	148.26	33.15	-47.34	91.44	.665	29	.514
i-ə	231.90	335.53	61.26	106.61	357.19	3.786	29	.001
e - ɛ	-4.22	72.53	13.96	-32.92	24.47	-.302	26	.765
ɔ - o	177.65	104.55	23.38	128.72	226.58	7.599	29	.000
ɷ - u	-118.75	149.18	30.45	-181.74	-55.76	-3.900	23	.001

The paired vowels test results for Nanuni provided nearly insignificant differences between [i] and [□]. The results in table 10 displays the significance for [i]-[□] as *t*(29)=.665,*p*<.514. The table displays a high degree of significant difference for the vowel pairs [i]-[ə], [ɔ]-[o] and [ɷ]-[u] at *t*(29)=3.786, *p*>.001, *t*(29)=7.599, *p*>.000 and *t*(23)=-3.900, *p*>.001respectively. The results reveal that [i] and [ə] are produced differently by the Nanuni speakers. It also indicates that [ɷ] and [u] are different sounds as produced by the Nanuni speakers. The results also displayed no significant difference between the pair [e]-[ɛ]. The results of *t*(26)= -.302, *p*<.765 for [e]-[ɛ] shows that speakers of Nanuni produce [e] and [ɛ] in almost the same way. In the same vain, the results also shows that there is much similarity in the way [ɔ] and [o] are produce by the Nanuni speakers.

4.3.2 Paired Vowels Test for Nayahili

Table 11 shows the paired vowels test for the Nayahili dialect of Dagbani. The test shows that there is a high degree of non-significant difference between the pairs of vowels [i]-[□] and [e]-[ɛ]. Table 11 shows a significance of *t*(29)=.601, *p*<.553 and *t*(29)=.628, *p*<.535 for the pairs of vowels respectively. This is an indication that the Nayahili speakers produce each pair of vowels in much the same manner; that is without any significant difference.

Table 11: Paired Samples Test results showing the significant differences between vowels for Nayahili

Vowel pairs	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
i - □	19.00	173.21	31.62	-45.68	83.68	.601	29	.553
i-ə	372.67	445.91	81.41	206.16	539.17	4.578	29	.000
e - ɛ	16.40	143.08	26.12	-37.03	69.83	.628	29	.535
ɔ - o	170.93	99.16	18.10	133.91	207.96	9.441	29	.000
ɷ - u	-81.38	138.04	34.51	-154.93	-7.82	-2.358	29	.032

The same can not be said about the pairs of vowels [ ]i-[□], [ɔ]-[o] and [ɷ]-[u]. The results display a high degree of significance *t*(29)=4.578, *p*>.000,

t(29)=9.441, *p*>.000 and *t*(29)=-2.358, *p*>.032 for [i]-[ə], [ɔ]-[o] and [ɷ]-[u] respectively.

4.3.3 Paired Vowels Test for Tomosili

Table 12: Paired Samples Test results showing the significant differences between vowels for Tomosili.

Paired Vowels	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
i - □	36.47	106.41	19.43	-327	76.20	1.877	29	.071
i-ə	447.57	562.12	102.63	237.67	657.47	4.361	29	.000
e - ɛ	-38.23	135.59	24.76	-88.86	12.40	-1.544	29	.133
ɔ - o	143.40	104.04	19.00	104.55	182.25	7.549	29	.000
ɷ - u	-106.37	143.18	27.55	-163.01	-49.73	-3.860	26	.001

Table 12 shows the results for the paired vowel test for the Tomosili dialect. The results provide an indication of no significance *t*(29)=1.877, *p*<.071 and *t*(29)=-1.544, *p*<.133 for the pairs of vowels i-□ and e-□ respectively. The results for ɔ-o, i-ə and [ɷ]-[u] display a high degree of significance *t*(29)=7.549, *p*>.000, *t*(29)=4.361, *p*>.000 and *t*(26)=-3.860, *p*>.001 respectively. Thus, the results give an indication that the Tomosili speakers produce [i] and [□] as well as [e] and [ɛ] with some similar characteristics. On the other hand, it clearly shows that each of the pairs of vowels [i]-[ə], [ɔ]-[o] and [ɷ]-[u] have different characteristics. Figure 9 confirms these statistical results.

4.3.4 Paired Vowel Test for Combined Means of the three Dialects

A final test for the paired vowels was performed on the overall mean values for the vowels of the 30 speakers. Results for the test are displayed in table 13. The table shows that no significant difference exist in the production of the paired vowels [i]-[□] and [e]-[ɛ]. However, it displays a high degree of significant difference for the paired vowels [i]-[ə], [ɔ]-[o] and [ɷ]-[u]. While [i]-[□] and [e]-[ɛ] showed no significant *t*(89)=.702, *p*<.485 and *t*(86)=-668, *p*<.506 respectively, [i]-[ə], [ɔ]-[o] and [ɷ]-[u] have shown a higher degree of significance *t*(89)=7.217, *p*>.000, *t*(89)=7.599, *p*>.000 and *t*(80)=-5.199, *p*>.000 respectively.

Table 13: Paired Samples Test results showing the significant differences between vowels using an overall combined mean values for the three dialects under study.

Paired Vowels	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
i - □	9.32	126.02	13.28	-17.07	35.72	.702	89	.485
i-ə	351.37	460.99	48.59	254.16	447.26	7.217	89	.000
e - ɛ	-8.84	123.38	13.23	-35.14	17.46	-.668	86	.506
ɔ - o	124.79	155.78	16.42	92.16	157.42	7.599	89	.000
ɷ - u	-83.49	144.52	16.06	-115.45	-51.54	-5.199	80	.000

The results of the overall mean suggest that there are no significant differences between the sounds [i] and [□]; and [e] and [ɛ] in Dagbani. On the other hand, the significant differences within the pairs of vowels [i]-[ə], [ɔ]-[o] and [ɷ]-[u] are indications that each of the sound [i, ə, ɔ, o, ɷ, u] is a sound independent of another in Dagbani. Figure 12 (the overall Dagbani vowel plot) in section 4.2.3 confirms these characteristic features of Dagbani vowels.

4.4 Test for Gender significance

A Oneway ANOVA test was performed on the mean values of speakers' F1 and F2 to assess the significant differences that exist between the vowels of male and female speakers of Dagbani. The test was performed separately for individual dialects, and finally a combined mean was tested for the three dialects. These tests were performed at 95% confidence level with *p* at a significant level of .05.

4.4.1 Statistical Results for Gender Significance

The results for Nanuni displayed some degree of gender significance for speaker F1 for the vowels [e, ɛ, a], with the least significance in [ɛ] (F(1,8)=6.462, p>.035). F1 displayed no significance for [i, □, ə, ɔ, ɷ, u]. The test for F2 revealed a high degree of significance difference for the front vowels [i, □, e, ɛ]. [ə] and [a] also displayed some degree of significance for F2.

The test for Nayahili revealed a higher degree of significance for speakers' F1 for the vowels [i, e, ɛ, a, o, ɷ]. [□, ə, ɔ, u] displayed non-significance from a least of F(1,8)=4.153, *p*<.076 for [ɔ] to a highest of F(1,8)=.648, *p*<.444 for [u]. F2 for the

same dialect displayed some degrees of gender significance from a least of F(1,8)=6.952, *p*>.030 in [o] to a highest of F(1,8)=24.477, *p*>.001.
Tomosili displayed gender significance for speakers' F1 for [i]. The other vowels displayed no significant difference for F1. The dialect on the other hand displayed significant F2 differences for the vowels [i, □, e, ɛ, a, ɔ]. The results showed that there are no significant F2 differences between male and female speakers of Tomosili for the vowels [ə, o, ɷ, u].

The test for the combined means for the dialects displayed no significant difference for the groups with the least value (F(1,28)=3.746, *p*<.063) in [□] and the highest (F(1,25)=.377, *p*<.545) in [u]. The test for F2 displayed some degrees of gender significant gender differences for [i] and [□] at F(1,28)=5.332, *p*>.063 and F(1,28)=9.422, *p*>.005 respectively. The other vowels [ə, e, ɛ, a, ɔ, o, ɷ, u] displayed no significant for gender with the value of *p* ranging from F(1,28)=9.422, *p*<.077 in [ə] to F(1,25)=.027, *p*<.871 in [u].

4.4.2 Formant Frequency Results for Gender Significance

Figure 13 is the scatter plots of the vowels at target position distinguishing gender for all speakers under study. Formant frequency values used for the scatter plot can be seen in Appendix B while the overall mean values and standard deviation for the formant frequencies of Dagbani vowels indicating gender plotted in Figure 14 can be seen in Table 14. Figure 14 shows the overall mean plots of speakers comparing gender for both long and short vowels of Dagbani.

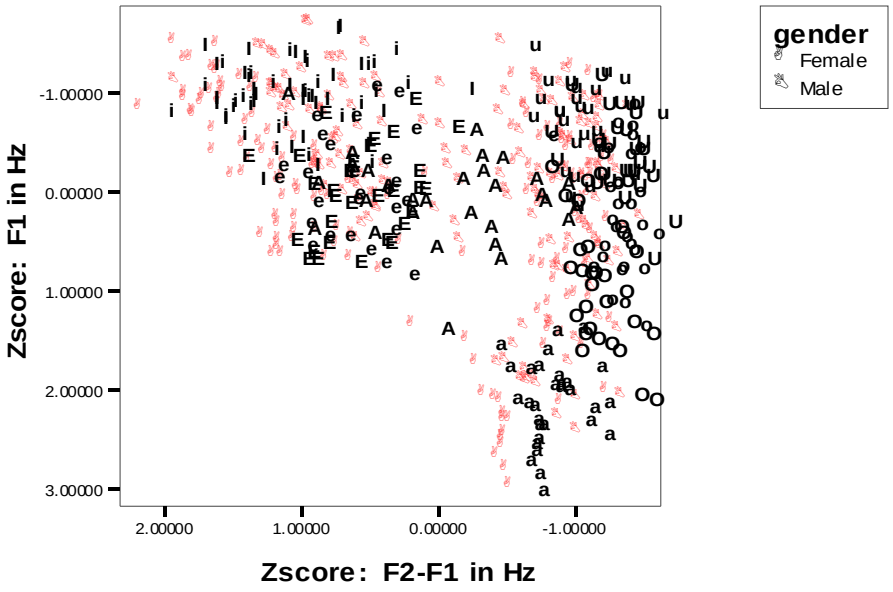


Figure 13: F1/F2-F1 speaker mean scatter plot of the vowels testing gender for the three dialects (Nayahili, Nanuni and Tomosili). I=ɪ; E=ɛ; A=ə; O=ɔ; U=ɷ

Table14: Overall mean values and standard deviation for the formant frequencies of Dagbani vowels indicating gender

VOWEL		MALE			FEMALE		
		F1	F2	F2’	F1	F2	F2’
i	Mean	351	2101	1750	337	2322	1985
	Std.	41	250		39	272	
□		358	2069	1711	322	2328	2006
Mean		52	249		49	212	
std.							
ə		492	1574	1082	463	1800	1337
Mean		41	323		69	351	
std.							
e	Mean	438	1966	1528	475	2100	1625
	std.	73	118		60	323	
ɛ		462	1989	1527	478	2128	1650
Mean		66	206		59	266	
std.							
a	Mean	740	1447	707	759	1534	775
	std.	61	113		39	153	
ɔ		563	1083	520	621	1099	478
Mean		95	97		60	285	
std.							
o	Mean	473	912	439	521	937	416
	std.	86	107		66	101	
ɷ	Mean	431	864	433	407	850	443
	std.	55	110		43	88	
u	Mean	382	984	602	368	993	625
	std.	55	160		58	121	

The differences between male and female vowel spaces are very clear. The results are primarily the effect of physiological differences between the male and female vocal tracts. Figure 14 shows the superimposed average male and female F1/F2-F1 vowel spaces at target. The male vowel space is nearly the same shape as the female vowel space; however, it is contained in the female vowel space as a result of lower frequencies, and shifted to the back of the vowel space.

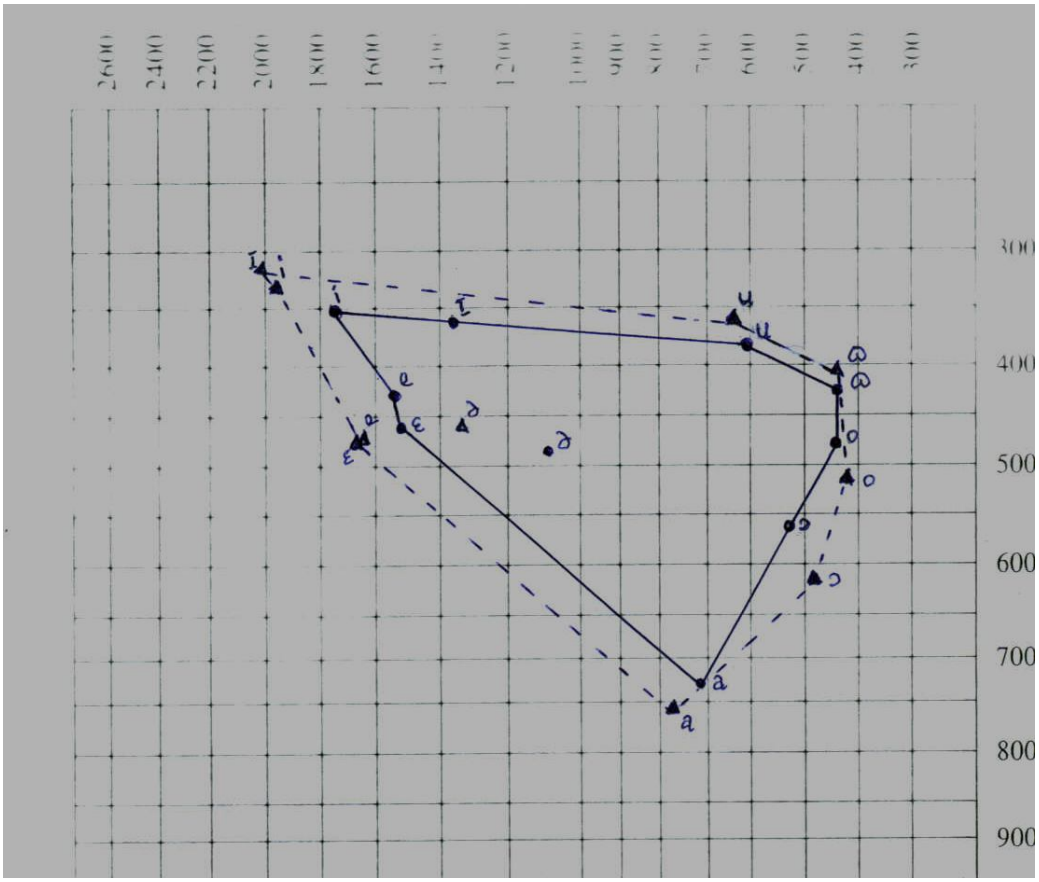


Figure 14: F1/F2 overall mean vowel plot for gender. ▲- - -▲= Female ●——●= Male

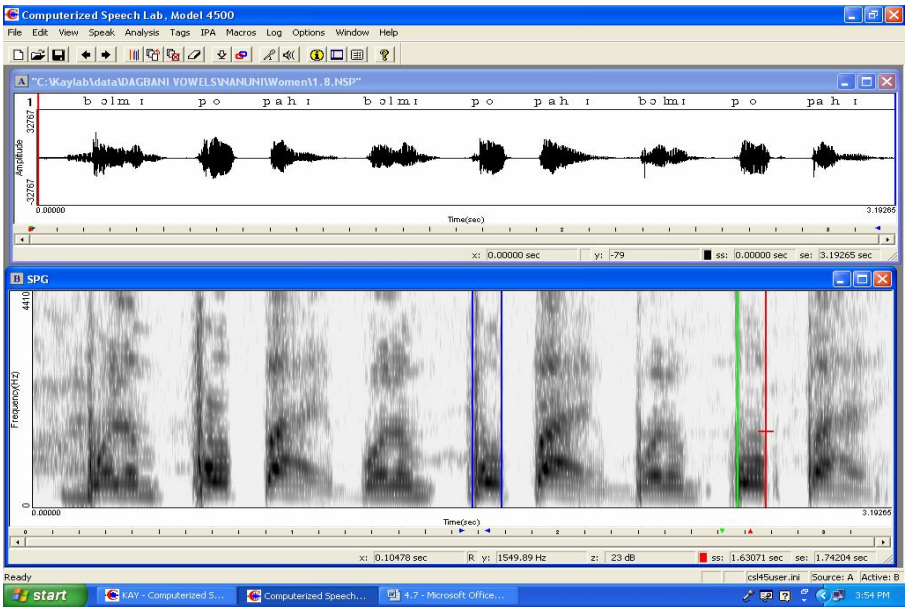
The differences between the male and female vowel in figure 14 are not uniform across all vowels or the formants. This finding supports Fant's (1966) conclusion of non-uniform relationship between male and female data.

Figure 14 shows that for both the first and second formants, there are very small differences between male and female values for the back vowels [o], [ɷ] and [u], [ɔ] and [a]. These differences are not significant. Significant F2-F1 differences occur for the high front vowels [i, □] as well as [ə], and [e, ɛ]. This is indicative of their fronted nature. Figure 14 also indicates that the females do not distinguish between [e, ɛ] as well as [i, □]. The case of the males is different with their [□] being towards the high mid area and [ɛ] slightly lower than [e]. The small F1 difference for the high front vowels in the present data is in line with Fant's finding that F1 between males and females for high front vowels is minimal.

4.5 Duration Analyses

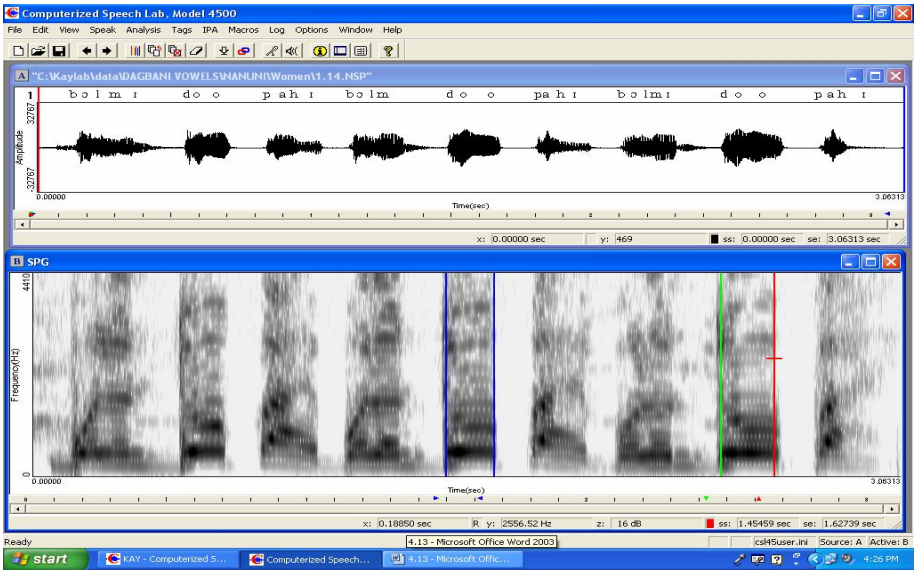
Speakers' vowel durations were analyzed to examine the differences in length between the traditional long and short vowels of Dagbani. To measure the duration of the vowel, the spectrogram for each vowel was enveloped by two cursors at its study state and the measurement taken in seconds. The CSL software provides the duration figures automatically through the placement of the

15(a)



[o]

15(b)



[o:]

Figure 15: Spectrograms of [o] and [o:] showing how their durations were taken.

cursors. The duration value for each vowel was read from the lower part of the spectrogram. The duration values and sample spectrograms from which the durations were measured can be found in the appendix of this work. Figures 15(a) and 15(b) show the duration measurements for the vowels [o] and [o:] for Nanuni speaker 6.

4.5.1 Durational characteristics of the vowels

The means for the absolute duration values for speakers of the dialects are given in Table 15, a comparison of the long and short vowels are in Table 16 while those of the overall mean duration values for the speakers are given in Tables 17 and 18. Figure 16 is an illustration of the lengths of all vowels compared between the three dialects of Dagbani. Vowel length pattern within the three dialects is not uniform across all vowels. Figure 16 shows that there are no significant vowel length differences between the dialects for the short front vowels [i], [□] and [ɛ].

Table 15: The mean duration values for all vowels measured in milliseconds.

VOWEL	DURATION		
	NANUNI	NAYAHILI	TOMOSILI
i	104.4	106.6	118.4
□	103.8	113.9	109.7
ə	108.5	114.6	115.4
e	117.7	140.1	114.3
ɛ	116.9	123.7	118.4
a	109.7	113.4	113.4
ɔ	117.6	118.4	120.7
o	113.7	120.9	118.2
ɷ	107.7	119.8	117.8
u	106.0	124.8	116.6
i:	161.5	182.5	185.7
e:	182.0	201.0	206.6
a:	175.4	180.5	212.2
o:	170.8	180.1	216.2
u:	160.5	154.1	200.4

However, [e] shows some difference with Nayahili being the longest those of Nanuni and Tomosili are almost the same length. For the long front vowels [i:] and [e:], differences in length exist with Tomosili being the longest, followed by Nayahili and Nanuni respectively in each case. The figure also shows that the central vowels [ə] and [a] have no length differences among the dialects.

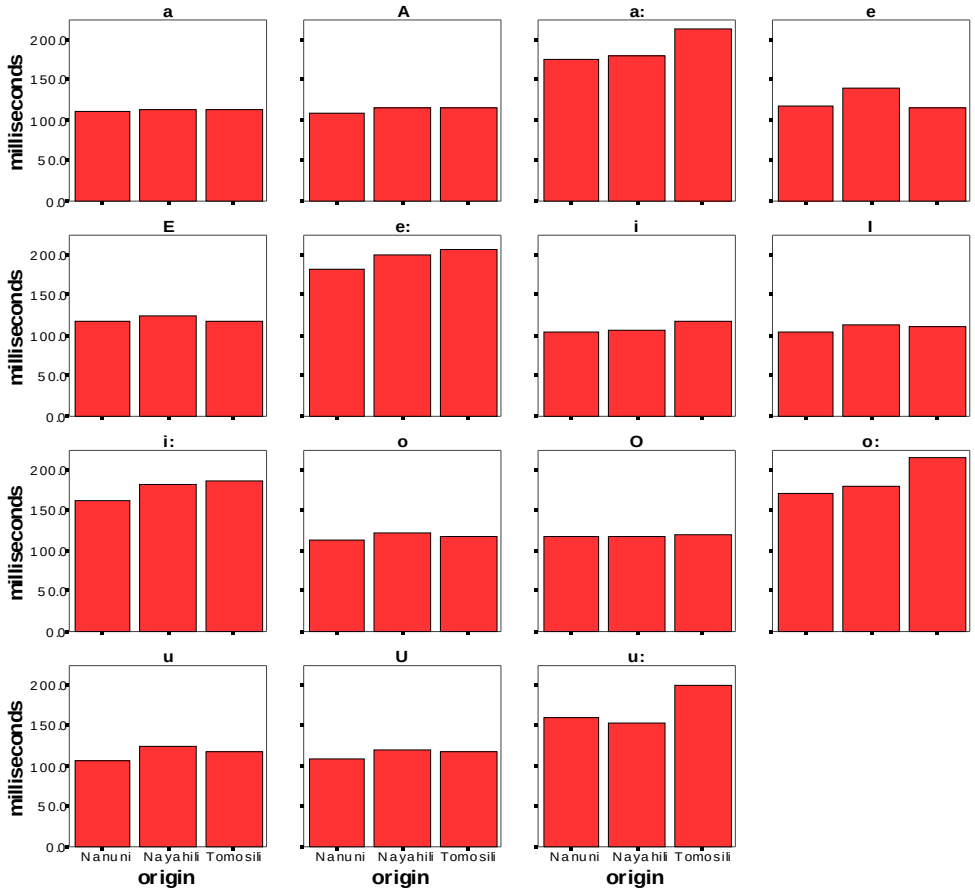


Figure 16: The lengths of all vowels compared between the three dialects. I=□, A=ə, E=ɛ, O=ɔ, U=ɷ

Table 16: Comparing durations of the short and long vowels for the dialects

Vowel	Nanuni		Nayahili		Tomosili	
	short	Long	Short	Long	Short	Long
I	104.4	161.5	106.6	182.5	118.4	185.7
E	117.7	182.0	140.1	201.0	114.3	206.6
A	109.7	175.4	113.4	180.5	113.4	212.2
O	113.7	170.8	120.9	180.1	118.2	216.2
U	106.0	160.5	124.8	154.1	116.6	200.4

The short back vowels [ɔ] and [o] showed no length differences among the dialects while [u] appeared longest for Nayahili, followed by Tomosili and Nanuni

respectively. The long back vowels show differences with Tomosili being the longest while Nayahili and Nanuni had almost the same lengths in each case. These durational characteristics are evident in the duration values in Table 15.

Generally, none of the dialects have displayed any significant length differences in their vowels, however, where some variations occur, vowels of Tomosili appear to be longest in duration. These results are evident in Figure 17 as the proportions of the vowels for the dialects are almost equal in length.

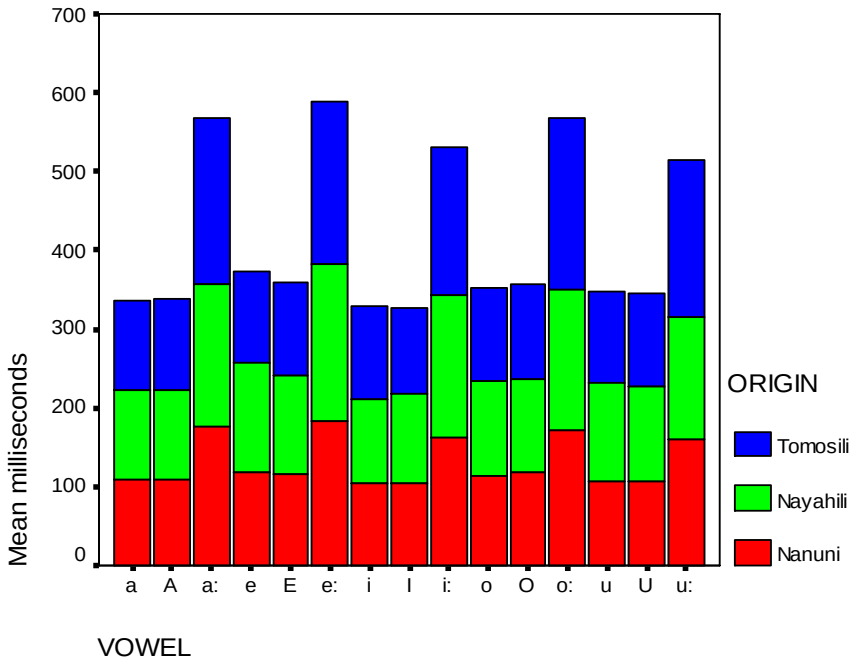


Figure 17: The proportions of total mean vowel duration averaged across all dialects. I=□, A=ə, E=ɛ, O=ɔ, U=ɷ

It is clear from Figure 17 and Table 15 that significant length differences exist between the long vowels and their shorter counterparts. [o], [i] and [e] are respectively between 61-63% the length of their longer counterparts. [a] and [u] are 59% and 67% the length of their longer counterparts respectively. The proportion of the total duration of the short vowels to their longer counterparts is 62.4%.

Table 17: Overall mean duration values for the vowels in milliseconds.

Vowel	Duration

I	109.8
□	109.8
ə	112.8
E	124.4
ɛ	119.5
A	112.2
ɔ	118.9
O	115.9
ɷ	115.1
U	115.8
i:	176.6
e:	196.6
a:	189.3
o:	189.1
u:	171.7

Generally, there are no significant length differences between the short vowels. The duration values in Table 15 and Figure 17 reveal these duration characteristics.

Table 18: comparison of the overall mean durations for the speakers

Vowel	Duration	
	Short	long
I	109.8	176.6
E	124.4	196.6
A	112.2	189.3
O	115.5	189.1
U	115.8	171.7

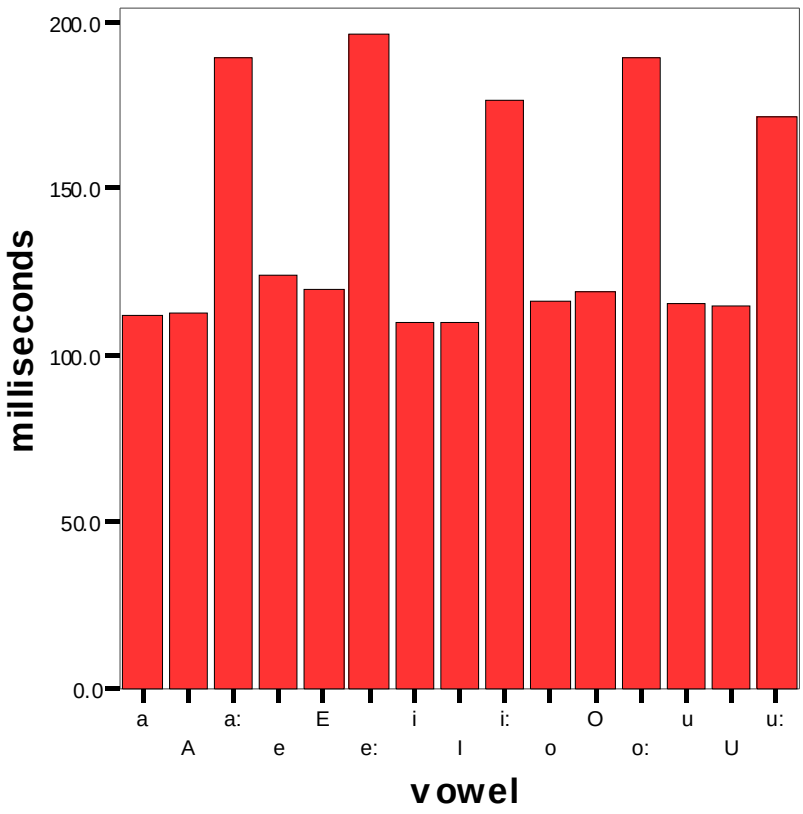


Figure18: The lengths of the vowels in milliseconds for the speakers. I=□, A=ə, E=ɛ, O=ɔ, U=ɷ

4.5.2 Gender characteristics of vowel duration

Table 19 provides the means duration values in milliseconds for all vowels for male and female speakers. Figure 19 illustrates the differences between the vowel duration of each vowel for males and females. It is clear from the graph that length of vowels is not uniform across all vowels for the gender.

The illustration shows that males produce longer short back vowels On the other hand; the females produced longer short front vowels as compared to those of the males. The male speakers have however produced longer long vowels with the exception of [u:] as compared to those of the female speakers. These patterns are evident in the mean duration values in Table 19 and Figure 19. Oneway ANOVA test (Table 20) showed that duration difference for male and female was statistically not significant for all vowels. This result is evident in the proportions for male and female in Figure 20.

Table 19: The mean duration values for the vowels in milliseconds for males and females

VOWEL	DURATION	
	Male	Female
I	98.9	120.6
□	99.3	118.9
ə	116.2	109.5
E	125.6	123.1
ɛ	113.3	124.8
A	118.0	106.3
ɔ	123.7	114.1
O	123.6	108.2
ɷ	124.2	106.0
U	125.3	106.3
i:	189.2	163.9
e:	201.2	191.8
a:	196.1	182.6
o:	194.1	183.4
u:	167.7	175.7

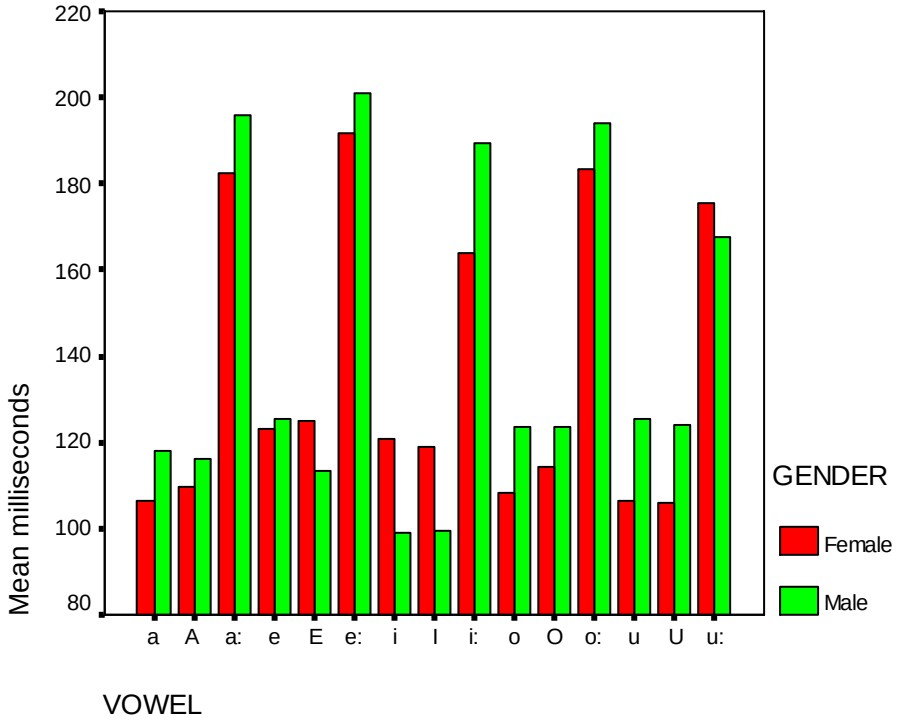


Figure 19: The differences between males and females for the total vowel duration in milliseconds. I=□, A=ə, E=ɛ, O=ɔ, U=ɷ

Table 20: Oneway ANOVA test results for duration gender comparison

Vowel	*F*	*P*
I	3.008	.102
□	2.783	.115
ə	.226	.641
E	.023	.882
Ɛ	1.549	.232
A	1.162	.297
□	.763	.395
O	1.772	.202
□	1.881	.189
U	1.383	.257
I:	1.268	.277
E:	.155	.699
A:	.327	.575
O:	.160	.659
U:	.180	.747

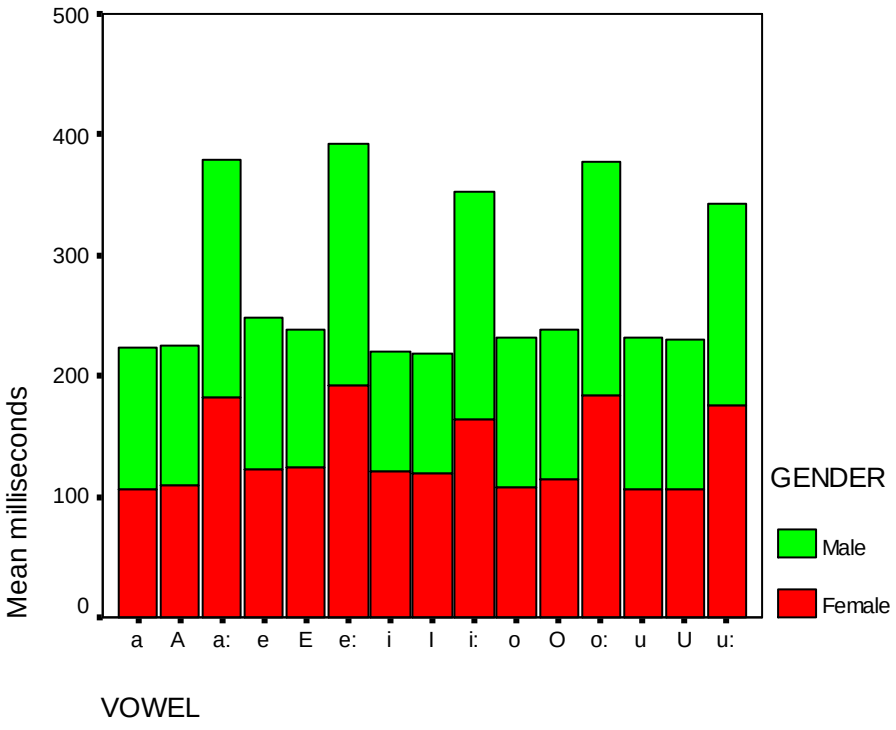


Figure 20: The proportions of total mean vowel duration indicating differences between males and females. I=□, A=ə, E=ɛ, O=ɔ, U=ɷ